

## Single-Walled Carbon Nanotubes for a Strain-based Magnetometer

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## Outline

- Motivation
- Background – CNT properties
- Magnetometer design, fabrication
- Measurements: Magnetic Field, Temperature
- Recent progress
- Thin Film Catalyst
- Preliminary device
- Conclusions and Future Work

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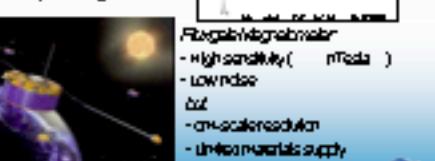
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## Motivation

- Applications:  
- Magnetospheric Science  
- Spacecraft Orientation  
- Planetary Geomagnetism



Rugby Magnetometer

- high sensitivity (~mTads)
- low noise
- fast
- no scale reduction
- uniform materials supply

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## Concept: Strain-based Magnetometer

- Use electromechanical materials to transduce torque on ferromagnetic needle into electric signal
- Reduce mass, footprint, power consumption
- Micofabrication → sensor array for spatial resolution

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## Single-Walled Carbon Nanotubes

- 1D metal/semiconductor  
- Elastic Mod. SWNT  $\approx 10^{-1}$  Pa  
- Cross-hold mobility  
-  $\sim 10^5$  cm<sup>2</sup>/Vs  
- Thermally, chemically stable

- Modifiable electronic properties:  
- Electric field (E)  
- Polar liquids and gases (chem sensing)  
- Mechanical deformation



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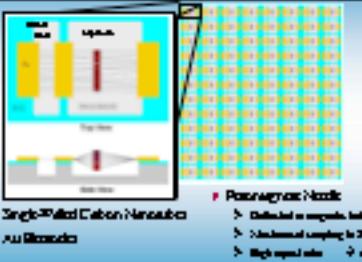
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## NanoMagnetometer Design



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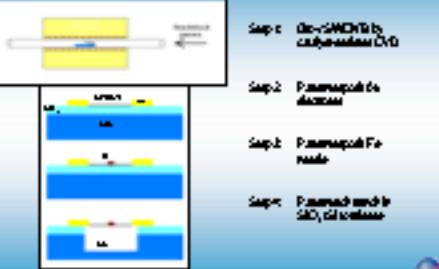
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## Growth and Fabrication



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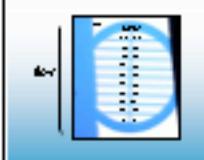
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## Precursor Device

- Catalyst =  $\text{Fe}(\text{NO}_3)_3$
- $T_d \approx 850^\circ\text{C}$
- CtAu electrodes



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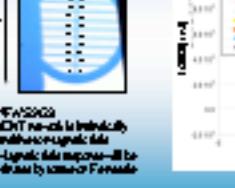
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## Magnetic Field Measurements

- Catalyst =  $\text{Fe}(\text{NO}_3)_3$



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SWCNT needs to initially  
minimize magnetic field  
- High response will be  
addressed by choice of catalyst

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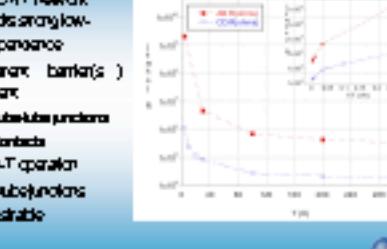
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## Temperature Dependence

- SWCNT network exhibits very low temperature dependence
- Apparent barrier(s) present
  - tube/tube junctions
  - contacts
- high temperature heterostructures unusable



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## Recent Progress

- Improve SWCNT growth (density, tube length, uniformity) using thin film Fe catalyst
- Intermediate step to magnetometer fabricated

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## Thin Film Fe Catalyst

- High density
- Improved cleanliness



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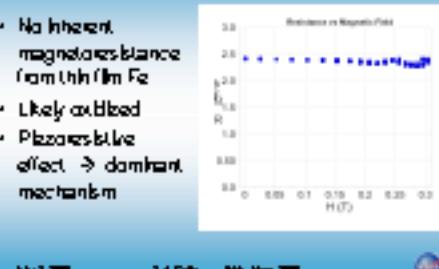
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## Thin Film Fe Catalyst



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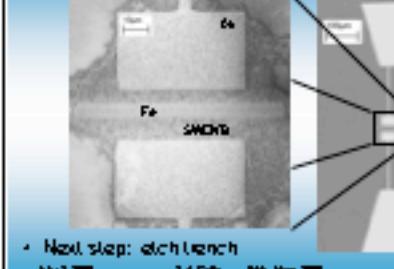
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## Further Developments: Preliminary Magnetometer Fabrication



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## Conclusions and Future Work

- Refined design, alternative materials for strain-based SWCNT magnetometer
- Magnetoresistance, temperature dependence of precursor SWCNT device
  - Heating junctions undesirable for minimum operating temperature range
  - No inherent magnetoresistive response to base metal
- Magnetoresistive fabrication nearing completion
  - Sensitivity performance to be tested
  - Results to be analyzed providing further development

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